



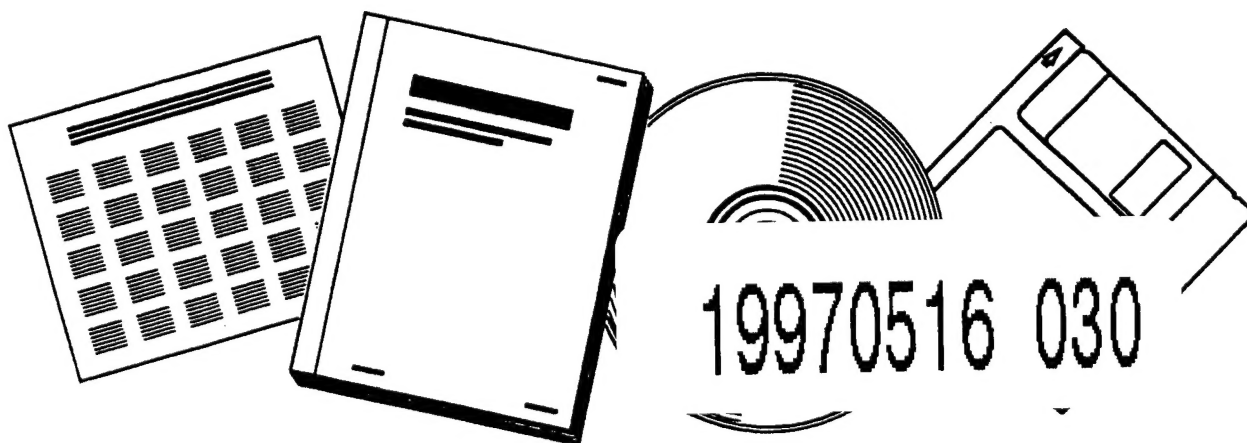
NUREGCR6190V1R1

NTIS
Information is our business.

PROTECTION AGAINST MALEVOLENT USE OF VEHICLES AT NUCLEAR POWER PLANTS: VEHICLE BARRIER SYSTEM SITING GUIDANCE FOR BLAST PROTECTION

U.S. ARMY CORPS OF ENGINEERS, OMAHA DISTRICT
OMAHA, NE

DEC 94



U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

EXIC QUALITY INSPECTED 3

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

M 96-07-1803

Protection Against Malevolent Use of Vehicles at Nuclear Power Plants

Vehicle Barrier System Siting Guidance for Blast Protection

Prepared by
D. T. Nebuda

U.S. Army Corps of Engineers

Prepared for
U.S. Nuclear Regulatory Commission

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 2120 L Street, NW., Lower Level, Washington, DC 20555-0001
2. The Superintendent of Documents, U.S. Government Printing Office, P. O. Box 37082, Washington, DC 20402-9328
3. The National Technical Information Service, Springfield, VA 22161-0002

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC bulletins, circulars, information notices, inspection and investigation notices; licensee event reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the Government Printing Office: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, international agreement reports, grantee reports, and NRC booklets and brochures. Also available are regulatory guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG-series reports and technical reports prepared by other Federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions. *Federal Register* notices, Federal and State legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Office of Administration, Distribution and Mail Services Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, Two White Flint North, 11545 Rockville Pike, Rockville, MD 20852-2738, for use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018-3308.

DISCLAIMER NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use, or the results of such use, of any information, apparatus, product, or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights.

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER
(Assigned by NRC. Add Vol., Supp., Rev.,
and Addendum Numbers, if any.)

NUREG/CR-6190
Vol. 1, Rev. 1

2. TITLE AND SUBTITLE

Protection Against Malevolent Use of Vehicles at
Nuclear Power Plants

Vehicle Barrier System Selection Guidance for
Blast Protection

3. DATE REPORT PUBLISHED

MONTH YEAR

December 1994

4. FIN OR GRANT NUMBER

A0400

5. AUTHOR(S)

D. T. Nebuda

6. TYPE OF REPORT

7. PERIOD COVERED (Inclusive Dates)

8. PERFORMING ORGANIZATION - NAME AND ADDRESS (If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)

U.S. Army Corps of Engineers, Omaha District
Protective Design-Mandatory Center of Expertise
215 North 17th Street
Omaha, NE 68102-4978

9. SPONSORING ORGANIZATION - NAME AND ADDRESS (If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)

Division of Technical Support
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

This manual provides for determining the minimum safe standoff distance between vital safety related equipment and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. Vital safety related equipment should survive the design basis vehicle bomb attack when the minimum safe standoff distance is provided. Guidance is provided for exposed vital safety related equipment and for equipment housed within vital area barriers.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

Vehicle, bomb, distance, bomb blast, vehicle barriers, blast loads,
malevolent, barrier, blast, safe distance, barrier systems, vital
barriers, explosives, land vehicle

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

(This Page)

Unclassified

(This Report)

Unclassified

15. NUMBER OF PAGES

16. PRICE

Protection Against Malevolent Use of Vehicles at Nuclear Power Plants

Vehicle Barrier System Siting Guidance for Blast Protection

Manuscript Completed: November 1994
Date Published: December 1994

Prepared by
D. T. Nebuda

U.S. Army Corps of Engineers, Omaha District
Protective Design-Mandatory Center of Expertise
215 North 17th Street
Omaha, NE 68102-4978

Prepared for
Division of Technical Support
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
NRC Job Code A0400

ABSTRACT

This manual provides guidance for determining the minimum safe standoff distance between vital safety related equipment and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. Vital safety related equipment should survive the design basis vehicle bomb attack when the minimum safe standoff distance is provided. Guidance is provided for exposed vital safety related equipment and for equipment housed within vital area barriers.

Contents

Section	Page
1 Introduction	1
1.1 Purpose	1
1.2 Protection Strategy	1
1.3 Scope	1
1.4 Organization	1
2 Design Basis	2
3 Determining Standoff Distance	3
3.1 Purpose	3
3.2 Definition	3
3.3 Obstructed Facilities	3
3.4 Maximum Considered Standoff Distance	3
4 Determining Minimum Safe Standoff Distance for Equipment Within Vital Area Barriers	4
4.1 Purpose	4
4.2 Basis of Tables	4
4.3 Types of Blast Loads	4
4.4 Assessment Tables	5
4.5 Pressure Leakage	6
5 Determining Minimum Safe Standoff Distance for Exposed Equipment	9
5.1 Purpose	9
5.2 Basis of Minimum Safe Standoff Distances	9
5.3 Heavy Equipment	9
5.4 Light Equipment	9
5.5 Water Tanks	9
6 Documentation	10

Contents (Cont'd)

Section	Page
7 Conclusions	11

Tables

4.1 Minimum Safe Standoff Distances for 12-Inch-Thick One-Way Slabs	6
4.2 Minimum Safe Standoff Distances for 18-Inch-Thick One-Way Slabs	7
4.3 Minimum Safe Standoff Distances for 12-Inch-Thick Two-Way Slabs	7
4.4 Minimum Safe Standoff Distances for 18-Inch-Thick Two-Way Slabs	7
4.5 Minimum Safe Standoff Distances for 24-Inch-Thick Two-Way Slabs	8
4.6 Minimum Safe Standoff Distances for 30-Inch-Thick Two-Way Slabs	8

SECTION 1 - INTRODUCTION

1.1 Purpose

This manual provides guidance for determining the minimum safe standoff distance between common vital safety related equipment (hereafter referred to as equipment) and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. The guidance presented can be used to determine the adequacy of standoff distance from an existing vehicle barrier system (VBS) or it can be used for the siting of a new VBS. The user of this manual should either have a background in civil engineering or should consult a civil engineer when using the manual.

1.2 Protection Strategy

Protection from blast effects is primarily accomplished by keeping the explosive source at a distance from the target. This distance is referred to as standoff distance. The amount of standoff distance required to provide an acceptable level of protection to a vital area is a function of the quantity of explosives considered and the type of vital area barrier, if any, used. For bombs transported by vehicles, providing standoff distance is accomplished by installing a VBS. For further information on VBS refer to Volume 2 of this NUREG.

1.3 Scope

This manual presents procedures for determining the minimum safe standoff distance for equipment that is either exposed or housed within vital area barriers. The procedure for exposed

equipment is based on Department of Defense explosive safety criteria and analytical modeling. The procedure for equipment housed within vital area barriers is based on dynamic nonlinear blast analysis for several different vital area barriers. Vital area barriers considered are planar one- and two-way acting reinforced concrete slabs. These slabs may be either wall or roof slabs. The minimum safe standoff distance applies only to walls and roofs and not to doors, windows, and louvers. Vital area barriers and exposed equipment not addressed will require analysis beyond the scope of this manual. The procedures described in the manual are accepted ways of determining the minimum safe standoff distance; however, they are not exclusive. Other procedures based on sound scientific and engineering principles are also acceptable. More rigorous analysis may result in lesser standoff distances than are given in this manual.

1.4 Organization

Guidance for determining minimum safe standoff distance is organized into the sections indicated below.

<u>Section</u>	<u>Topic</u>
2	Design Basis
3	Determining Standoff Distance
4	Determining Minimum Safe Standoff Distance for Equipment Within Vital Area Barriers
5	Determining Minimum Safe Standoff Distance for Exposed Equipment
6	Documentation
7	Conclusions

SECTION 2 - DESIGN BASIS

The design basis vehicle bomb threat that equipment must resist is an explosive weight in terms of its equivalency to TNT. The design basis vehicle bomb threat and protection criteria have been provided to affected Nuclear Regulatory Commission (NRC) licensees in a separate document. The threat information, and any information derived from it, has been determined by the NRC to be Safeguards Information, and it should be handled accordingly.

SECTION 3 - DETERMINING STANDOFF DISTANCE

3.1 Purpose

This section defines the standoff distance that a vehicle barrier system (VBS) provides equipment.

3.2 Definition

For the purposes of this NUREG, the standoff distance for exposed equipment is defined as the shortest distance from the equipment to the closest exterior point of the VBS and the standoff distance for equipment housed within vital area barriers is defined as the shortest distance from the center of the face of the barrier to the closest exterior point of the VBS. Certain types of vehicle barriers, due to performance characteristics, require additional distance from the vital barriers or vital equipment to provide adequate protection. Refer to Volume 2 of this NUREG for information on the

additional distance that needs to be provided beyond the minimum safe standoff distances cited in this volume.

3.3 Obstructed Facilities

In situations where an obstruction exists between the exposed equipment or vital area barrier and the VBS, in the absence of rigorous analysis, the obstruction should be disregarded and the stand-off distance determined as defined in paragraph 3.2.

3.4 Maximum Considered Stand-off Distance

If a standoff distance of 360 feet or greater is provided, no further analysis is required. It can be assumed that the equipment will be provided adequate protection.

SECTION 4 - DETERMINING MINIMUM SAFE STANDOFF DISTANCE FOR EQUIPMENT WITHIN VITAL AREA BARRIERS

4.1 Purpose

This section provides tables, with instructions, that can be used to determine minimum safe standoff distances for select one- and two-way reinforced concrete vital area barriers.

4.2 Basis of Tables

The tables presented in this section are based on the U.S. Army Corps of Engineers Protective Design - Mandatory Center of Expertise Technical Report PDC-TR 91-6, *Blast Analysis Manual, Part 1 - Level of Protection Assessment Guide*. Simplifying assumptions have been applied to the procedures contained in this document for both one- and two-way reinforced flat concrete slabs subject to airblast loads. These simplifying assumptions allow for expedient, conservative determination of the minimum safe standoff distance. The minimum applicable standoff associated with the design threat and the response mode valid for this procedure is 36 feet. The assumptions made on input parameters for the PDC-TR 91-6 chart for one-way slabs are as follows:

Compressive strength of concrete - 4,000 psi
Yield strength of reinforcing - 60,000 psi
Acceleration due to gravity - 386.4 in/sec²
Weight density of section - 0.0868 lb/in³
Simple supports
Average depth of tensile reinforcing -
(thickness - 3 in)
Span length - less than or equal to 30 ft

The assumptions made on input parameters for the PDC-TR 91-6 chart for two-way slabs are as follows:

Compressive strength of concrete - 4,000 psi

Yield strength of reinforcing - 60,000 psi
Acceleration due to gravity - 386.4 in/sec²
Weight density of section - 0.0868 lb/in³
Simple supports
Boundary coefficient - 0.55 (ordinate term)
- 0.35 (abscissa term)
Average depth of tensile reinforcing -
(thickness - 3 in) for 12- & 18-in slabs
(thickness - 6 in) for 24- & 30-in slabs
Short span - greater than or equal to 8 ft
Aspect ratio - greater than or equal to 0.5

The only input parameters are thickness and reinforcing ratio. The tables are conservative for members with greater material strengths and/or support conditions and lesser spans. For the purposes of this manual, the minimum safe standoff distance is that associated with the medium level of protection defined in PDC-TR 91-6. If a slab has a total area of openings greater than 2 percent of the total slab area being analyzed, a more rigorous structural analysis of the slab beyond the scope of this manual is required. If the equipment is not protected from components such as doors, windows, hatches, and louvers, a more rigorous analysis will be needed to show that it will not be damaged should these components be disengaged by the blast. Section 4.5 provides guidance for determining the safe standoff distance from openings to prevent airblast damage to equipment contained within the facility.

4.3 Types of Blast Loads

For the purposes of this manual, blast loads are separated into the two categories of reflected and side-on. A reflected load occurs when the vital area barrier faces, or nearly faces, the explosive source and is at approximately the same

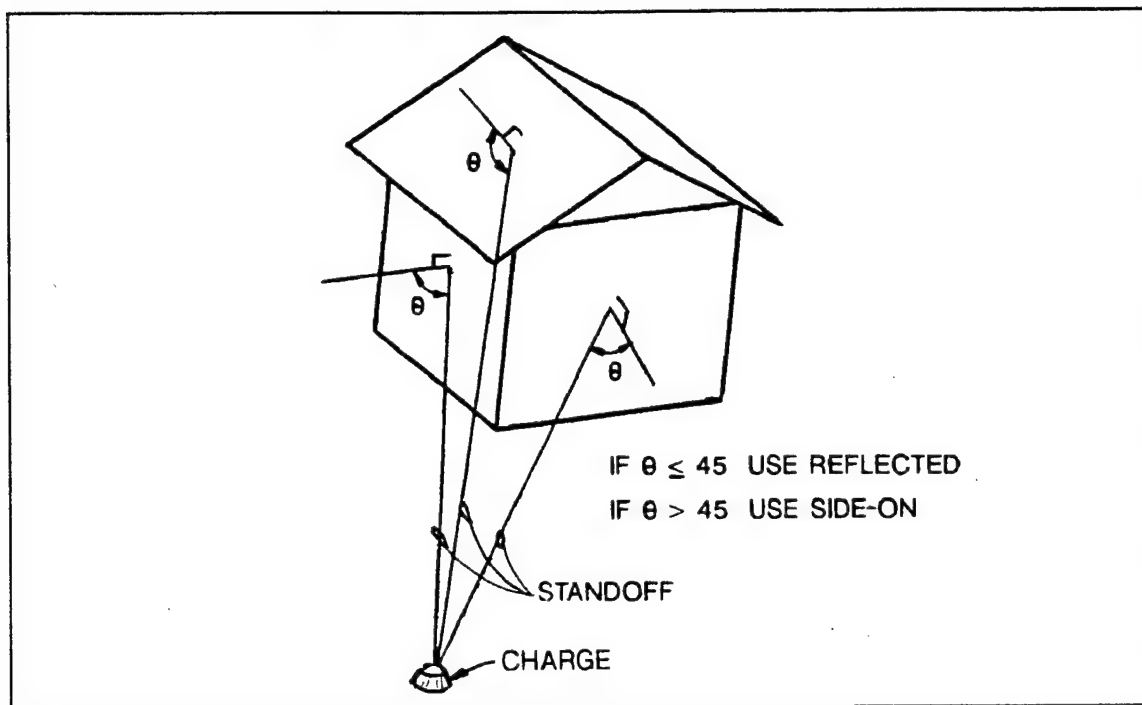


Figure 4.1 Criteria for using reflected or side-on blast loads

elevation. Side-on loading is applied to vital area barriers which do not face the explosive source or where the difference in elevation is large. Examples of vital area barriers which experience side-on loading are roofs, side walls, rear walls, and upper panels of the front wall of a tall building. When performing an assessment, loads can be defined using the following criteria in terms of the angle of the path of the blast wave with respect to a line perpendicular to the structural component from the center of the face:

- Angles less than or equal to 45 degrees, use reflected criteria
- Angles greater than 45 degrees, use side-on criteria

An illustration of this criteria is provided in figure 4.1.

4.4 Assessment Tables

Tables 4.1 and 4.2 represent two slab thicknesses and list five reinforcing ratios for one-way reinforced slabs. Tables 4.3 through 4.6 represent four slab thicknesses and list five reinforcing ratios for two-way reinforced slabs. Use the following steps with these tables.

4.4.1 Step 1

Determine if the tables apply to the vital area barrier to be considered; i.e., if the vital area barrier is a flat concrete slab with either one- or two-way reinforcing. If these tables do not apply, use an alternate analysis technique such as that contained in PDC-TR 91-6.

4.4.2 Step 2

Use as-built construction drawings to determine the slab thickness and reinforcing ratio. For

two-way members use the average of the long and short span tensile reinforcing ratios.

4.4.3 Step 3

Determine if the vital area barrier will be subject to reflected or side-on blast loading in accordance with the information presented in paragraph 4.3.

4.4.4 Step 4

Using the table for the thickness involved, move to the line for the appropriate reinforcing ratio. For thicknesses and reinforcing ratios greater than or between those provided in the tables, use the next lesser thickness or reinforcing ratio provided. Move across the row to the applicable blast loading criteria and read the minimum safe standoff distance.

4.4.5 Step 5

If the minimum safe standoff distance determined from the table is less than or equal to the existing or proposed standoff distance as defined

by Section 3.2 of this manual, document the analysis and move on to the next vital area barrier to be considered. If the minimum safe standoff distance is greater than the standoff distance provided or proposed as defined by Section 3.2 of this manual, perform a more rigorous analysis or adjust the siting of the vehicle barrier system (VBS) to provide a standoff distance equal to or greater than the minimum safe standoff distance.

4.5 Pressure Leakage

The following formula can be used to determine the minimum safe standoff distance, R, from penetrations in vital area barriers.

$$R = ((A/V) + 0.7007) / 0.001776$$

A = Area of penetration, ft²

V = Volume of room behind penetration, ft³

If this standoff distance cannot be achieved, a more rigorous analysis must be performed. Use the greater of the minimum safe standoff distances determined for vital area barriers or pressure leakage.

Table 4.1 Minimum safe standoff distances for 12-inch-thick one-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	86	36
0.8	98	36
0.6	120	48
0.4	158	70
0.2	282	138

Table 4.2 Minimum safe standoff distances for 18-inch-thick one-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	58	36
0.8	68	36
0.6	80	36
0.4	108	40
0.2	186	82

Table 4.3 Minimum safe standoff distances for 12-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	48	36
0.8	50	36
0.6	56	36
0.4	70	36
0.2	108	44

Table 4.4 Minimum safe standoff distances for 18-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	38	36
0.8	40	36
0.6	46	36
0.4	56	36
0.2	84	36

Table 4.5 Minimum safe standoff distances for 24-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	36	36
0.8	36	36
0.6	36	36
0.4	40	36
0.2	62	36

Table 4.6 Minimum safe standoff distances for 30-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	36	36
0.8	36	36
0.6	36	36
0.4	36	36
0.2	54	36

SECTION 5 - DETERMINING MINIMUM SAFE STANDOFF DISTANCE FOR EXPOSED EQUIPMENT

5.1 Purpose

This section provides the minimum safe standoff distances for aboveground equipment not housed within vital area barriers. Three categories of exposed equipment are addressed in this manual --heavy equipment, light equipment, and water tanks.

5.2 Basis of Minimum Safe Standoff Distances

The minimum safe standoff distances for heavy and light equipment are based on Department of Defense explosive safety criteria. The minimum safe standoff distance for water tanks is based on dynamic nonlinear finite element blast analysis.

5.3 Heavy Equipment

Heavy equipment, for the purposes of this manual, means equipment such as pumps,

pipng, valves, compressors, and motors. The minimum safe standoff distance for equipment of this type is 180 feet.

5.4 Light Equipment

Light equipment, for the purposes of this manual, means equipment such as ventilation equipment, electrical control panels, and switchgear. The minimum safe standoff distance for equipment of this type is 360 feet.

5.5 Water Tanks

The minimum safe standoff distance for water tanks that are maintained in a full or nearly full condition is 100 feet. This safe standoff distance includes considerations for airblast and fragmentation effects caused by the explosion.

SECTION 6 - DOCUMENTATION

Documentation guidelines are contained in
Regulatory Guide 5.68.

SECTION 7 - CONCLUSIONS

This manual provides guidance for determining the minimum safe standoff distance between common vital safety related equipment and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. The guidance presented can be used to determine the adequacy of standoff distance from an existing vehicle barrier system (VBS) or it can be used for the siting of a new VBS.

NTIS does not permit return of items for credit or refund. A replacement will be provided if an error is made in filling your order, if the item was received in damaged condition, or if the item is defective.

*Reproduced by NTIS
National Technical Information Service
U.S. Department of Commerce
Springfield, VA 22161*

This report was printed specifically for your order from our collection of more than 2 million technical reports.

For economy and efficiency, NTIS does not maintain stock of its vast collection of technical reports. Rather, most documents are printed for each order. Your copy is the best possible reproduction available from our master archive. If you have any questions concerning this document or any order you placed with NTIS, please call our Customer Services Department at (703)487-4660.

Always think of NTIS when you want:

- Access to the technical, scientific, and engineering results generated by the ongoing multibillion dollar R&D program of the U.S. Government.
- R&D results from Japan, West Germany, Great Britain, and some 20 other countries, most of it reported in English.

NTIS also operates two centers that can provide you with valuable information:

- The Federal Computer Products Center - offers software and datafiles produced by Federal agencies.
- The Center for the Utilization of Federal Technology - gives you access to the best of Federal technologies and laboratory resources.

For more information about NTIS, send for our FREE *NTIS Products and Services Catalog* which describes how you can access this U.S. and foreign Government technology. Call (703)487-4650 or send this sheet to NTIS, U.S. Department of Commerce, Springfield, VA 22161. Ask for catalog, PR-827.

Name _____
Address _____

Telephone _____

*- Your Source to U.S. and Foreign Government
Research and Technology.*